Desalination and Water Treatment
www.deswater.com
doi: 10.1080/19443994.2014.930696

55 (2015) 2196–2200
August

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Application of salt extracted peanut seeds in the pretreatment of palm oil mill effluent (POME)

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Received 12 August 2013; Accepted 29 May 2014

ABSTRACT

This paper presents a study on the effectiveness of salt extracted peanut seeds after oil extraction as a novel coagulant for turbidity, total suspended solids (TSS) and chemical oxygen demand (COD) removal in palm oil mill effluent (POME) pretreatment process. The coagulation activity was investigated for the peanuts seeds after its oil extraction. The active coagulation component was extracted using three different concentrations of sodium chloride (NaCl), namely 0, 1 and 2 mol/l. The initial turbidity, TSS and COD of POME were found to be 11,684 NTU, 22,784 and 63,955 mg/l, respectively. The results show that extraction of coagulation active component from peanut seeds using NaCl improved the removal efficiency of the tested constituents. Accordingly, the higher NaCl concentration resulted in a low optimum dosage of peanut seeds and higher removal of turbidity, TSS and COD. Peanut seeds extracted with 2 mol/l reduced TSS to 1,218 mg/l (94.7% removal). On the other hand, peanut seeds extracted with distilled water (0 mol/l) reduced TSS to 2,175 mg/l (90% removal). Analysis of the present results and their comparison with the literature indicate that the coagulation activity of the peanut cake could be due to its protein component.

Keywords: Peanut; Coagulation; POME; Pretreatment; COD

1. Introduction

Palm oil mill effluent (POME) is a highly polluted wastewater and it is many times more polluted than domestic sewage. The most common method of extracting palm oil from the fresh fruit bunch is the wet palm oil milling process. This method uses steam and water for oil extraction, which leads to about 60% of the used water to end up as POME. Palm oil production started in Malaysia in 1960s and at that time, the number of palm oil mills was around 10 mills [1]. This number of mills increased to 334 mills in 1999 and continued to increase rapidly to 426 mills in 2011

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[2]. For each tonne of crude palm oil (CPO) produced, it is estimated that 5–7.5 tonnes of water is used, and more than 50% of water ends up as POME. This implies that about 2.5–3.75 tonnes of POME will be generated per tonne of CPO production. This huge quantity of POME will pollute the water courses nearby the palm oil mills without proper waste management implemented in palm oil mills [2]. The local and outside demand for palm oil is making the palm oil industry a contributor to the Malaysian economy and in the year 1998, it contributed to about US $5.6 billion, which is almost 5.6% of the total GDP [3]. In order for Malaysia to continue its economic prosperity and environmental sustainability, a proper method of treating POME must be developed and further implemented in the mills. Almost 85% of Malaysian palm oil mills currently use the ponding system which requires large land areas and long detention time [1]. Another disadvantage of using ponding system is the emission of greenhouse gases mainly carbon dioxide and methane as it is estimated that from every one tonne of treated POME, 28 m^3 of gases were emitted to the environment [4]. It has been reported that many palm oil mills are facing difficulty in meeting the discharge requirement by the Department of Environment (DOE) of Malaysia which is 50 mg/l for biochemical oxygen demand (BOD) [5]. Different methods of POME treatment have been developed by some researchers. For instance, Bhatia et al. [6] carried out a study using *Moringa oleifera* seeds as a natural coagulant for pretreatment of POME and also examined whether the combination of *Moringa oleifera* seeds with a flocculant (NALCO 7751) can improve the removal efficiency. The study reported that *Moringa oleifera* seeds after oil extraction alone removed 95% of suspended solids (SS) and 52.2% of chemical oxygen demand (COD); and when *Moringa oleifera* seeds were combined with a flocculant (NALCO 7751) the removal efficiency of SS and COD increased to 99.3 and 52.5%, respectively. Performance of the coagulation–flocculation process under different temperatures was also investigated. Results revealed that temperature of 30˚C resulted in best removal efficiency among the other studied temperatures (40, 55 and 70˚C). Ahmad et al. [7] studied the option of using chitosan as a biodegradable coagulant in the removal of residual oil and suspended solids in POME and compared its performance with Aluminium sulphate (alum) and polyaluminium chloride (PAC). The results of the study showed that chitosan performed better than alum and PAC by removing almost 95% of suspended solids and oil at a dosage of 500 mg/l; whereas alum and PAC needed a dosage of 800 and 600 mg/l, respectively, in order to match the efficiency of chitosan. The pH value was adjusted from 3 to 6 in order to study its effect on the efficiency of coagulation [6,7]. It was found that the removal efficiencies of oil for the three coagulants were more than 95% at pH 4; however, the efficiency started to decline when the pH was adjusted to 5. In addition, the pH adjustment did not really affect the performance of chitosan for suspended solids removal, while the suspended solids removal efficiency for both alum and PAC declined drastically in alkaline condition. Ahmad et al. [7] concluded that the adjustment of pH can be neglected in POME since this will lower the cost of the treatment, and they also suggested that chitosan could substitute alum and PAC as an environmental friendly coagulant because it does not generate residual aluminium in the effluent which is hazardous to the nearby water course if discharged without treatment. Researchers are studying natural coagulants because it has been reported that many developing countries are facing difficulties in affording the cost burden of chemical coagulants and also due to the fact that the chemical coagulants produce large amount of sludge and residual aluminium in the treated water or wastewater. Vikashni et al. [8] investigated the ability of *Arachis hypogaea* (peanuts) for removal of heavy metals in Fiji's drinking water and it was observed that peanut seeds absorbed 8% of copper, 50% of lead, 10% cadmium, 40% chromium and 30% of zinc. Okuda et al. [9–11] studied the difference between extracting the active ingredients from *Moringa oleifera* seeds using distilled water alone and using distilled water and 1 mol/L NaCl. The study found out that the NaCl and distilled water extracted *Moringa oleifera* seeds removed 95% of turbidity at a dosage 7.4 times less than the water extracted *Moringa oleifera* dosage, which removed 75% of turbidity from the same water. The present study aims to investigate the effectiveness of peanut seeds after oil extraction as a coagulant for turbidity, TSS and COD removal for the POME pretreatment.

2. Materials and methods

2.1. Collection of peanut seeds

The peanut seeds were imported from the Republic of Sudan. The seeds were prepared by removing the seeds' coat by hand, and then they were crushed to powder using the normal home blender model National Deluxe Family Kitchen (MJ-C85N, Japan), after crushing they were kept in a sealed container and put into the refrigerator.

2.2. Extraction of oil from the peanut seeds

The oil extraction experiment was carried out at the laboratory using the soxhlet apparatus and *n*-hexane

(96% purity) as a solvent [6]. The extraction of oil from the seeds was carried out for nearly 7 h. The mass of the peanuts before and after the oil extraction was measured, and it was noted that 22% weight of edible oil could be extracted from the seeds as a valuable product.

2.3. Preparation of peanut stock solution

The stock solution was prepared by dissolving 14 g of peanut seeds powder in 280 ml distilled water to give a stock solution concentration of 50,000 mg/l. The concentration of salt (NaCl) used in this study was 0 mol/l (distilled water), 1 and 2 mol/l. Each mol/l of NaCl is equal to 58.4 g. Hence, for the stock solution of 1 mol/l NaCl, 16.352 g of NaCl was added to the stock solution whereas, 32.704 g of NaCl was added to the 2 mol/l stock solution. The stock solution was blended for 10 min using domestic blender model National Deluxe Family Kitchen (MJ-C85N, Japan). Different volumes were taken from the stock solution using Eq. (1) to obtain the required concentration (dosages):

$$C_1 \times V_1 = C_0 \times V_0 \tag{1}$$

where C_0 is the desired dosage of coagulant in each beaker (mg/l), V_0 is volume of effluent in each beaker (ml), C_1 is the concentration of the stock solution (mg/l) and V_1 is the required volume of stock solution (ml) corresponding to the desired dosage of peanut seeds.

The various dosages were calculated and applied to the coagulation experiments (jar test) for optimizing of peanut seeds extract.

2.4. POME samples

Samples of fresh raw POME were obtained from a local palm oil mill factory (Seri Ulu Langat Palm Oil Mill Dengkil, Kajang, Selangor, Malaysia). In order to avoid fermentation of the POME sample, all experiments were carried out on the same day of sample collection. The characteristics of POME can vary from time to time as well as from mill to mill, and they depend on several factors such as the quality and quantity of fruits processed and also the time of sample withdrawal. The obtained characteristics as shown in Table 1 were based on seven collections and there was a gap of three days between each collection. Such characteristics are almost similar to those characteristics of the POME obtained by Bhatia et al. [6]. For turbidity, BOD and COD measurement, dilution of POME sample was carried out since the concentration of these parameters was very high, hence, the instruments could not give the accurate reading without dilution.

2.5. Coagulation experiment

Jar tester (BIBBY Stuart Scientific, UK) was used to carry out the coagulation test. The jar test consisted of three stages: rapid mixing, slow mixing and sedimentation. Five hundred ml of POME was filled in a 1 l glass beaker placed on the slot in the jar tester. During the rapid mixing, the coagulant dosages were added simultaneously into the beakers using pipettes. Rapid mixing time, slow mixing time, settling time, rapid mixing speed and slow mixing speed were programmed in order to be automatically controlled. Table 2 shows the values of these parameters. After a settling time of 60 min, the samples were taken from the beakers. They were collected at a depth of 3 cm below the surface of POME in the beaker using a pipette. The turbidity of the samples was measured using Turbidimeter (HACH, Model 2100AN, USA).

3. Results and discussion

3.1. Effect of NaCl concentration on the coagulation ability of peanut seeds

Fig. 1 shows the variation of residual turbidity remaining in the supernatant after settling, as a function of peanut seeds' dosage. The initial turbidity of the POME was 11,684 NTU. The optimum dosage for 0, 1 and 2 mol/l NaCl was found to be 7,000, 6,000 and 5,000 mg/l, respectively, and the corresponding residual turbidity was 1,115, 750 and 625 NTU. This result shows that there was a significant effect of NaCl concentration in the coagulation activity in terms of reducing the coagulant's dosage as well as obtaining higher removal of turbidity. This result is in agreement with Birima et al. [12] and with other studies [9–11] as well. The former used peanut seeds after oil extraction to treat synthetic water with an initial turbidity varying from 208 to 214 NTU. Coagulant component was extracted with NaCl of which concentrations were ranged from 1 to 7 mol/l (with 1 mol/l increment). It was found that turbidity removal increased gradually by increasing the concentration of NaCl. Accordingly, the peanut seeds extracted by 6 mol/l NaCl could remove 92% of turbidity, whereas peanut seeds extracted by distilled water could remove only 31.5% for the same dosage. However, in the present study, the concentration of NaCl was limited to 2 mol/l for the economic consideration. Several

Table 1
Characteristics of POME in comparison with literature study

Parameter	Average value obtained in this study	Value obtained by [6]
Temperature	80˚C	80˚C
pH	4.35	4.5
Total suspended solids, TSS	18,537 mg/l	17,927 mg/l
Chemical oxygen demand, COD	44,933 mg/l	40,200 mg/l
Biochemical oxygen demand, BOD	22,000 mg/l	–
Turbidity	13,973 NTU	–

Table 2
Operating variables used for jar test

Rapid mixing speed (rpm)	150
Rapid mixing time (min)	5
Slow mixing speed (rpm)	30
Slow mixing time (min)	30
Settling time (min)	60

researchers [9,10,13] found that extracting the coagulation component from *Moringa oleifera* with salt solution could improve the removal of constituents from POME and turbid water.

The improvement of coagulation activity could be due to losing-up of the protein associations leading to more soluble and coagulation active species in solution. This mechanism was also proved by White et al. [13] and Voet and Voet [14] who found that addition of salt solution had enhanced the breaking of protein associations and leading to increased protein solubility. Ndabigengesere et al. [15] investigated the reason behind *Moringa oleifera* seed powder's ability to function as a coagulant, and they found that the active ingredients are mainly positively charged protein. According to this finding, it could be interpreted that the ability of peanut seeds to function as a natural coagulant could be due to its protein component.

3.2. Removal of TSS and reduction of COD

Fig. 2 shows the variation of residual TSS remaining in the supernatant after settling, as a function of peanut seeds' dosage for varying concentrations of NaCl, namely 0, 1 and 2 mol/l, on the other hand, Fig. 3 shows the variation of residual COD as a function of peanut seeds' dosage for the aforementioned concentrations. The same trend of turbidity removal is observed, whereby, the higher the NaCl concentration resulted in a lower optimum dosage and the higher TSS and COD removal. The initial TSS and COD were discovered to be 22,784 and 63,955 mg/l, respectively. The respective residual TSS for 0, 1 and 2 mol/l was found to be 2,175 (90% removal), 1,463 (93.6% removal) and 1,218 mg/l (94.7% removal). On the other hand, the residual COD for the three NaCl concentrations mentioned above were 21,645 (66% reduction), 21,398 (67% reduction) and 14,700 mg/l (73.5% reduction), respectively. This removal efficiency is almost similar to that obtained by Bhatia et al. [6] in terms of TSS removal and significantly better in terms of COD reduction. In the study, carried out by Bhatia et al. [6], *Moringa oleifera* seeds were used to treat POME and the corresponding removals achieved were found to be 95 and 52.2% for TSS and COD.

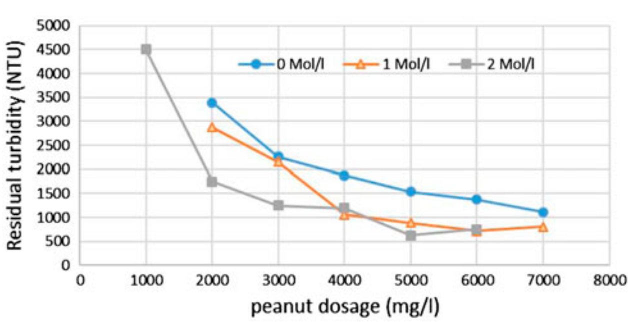

Fig. 1. Residual turbidity vs. peanut dosage under different NaCl concentrations.

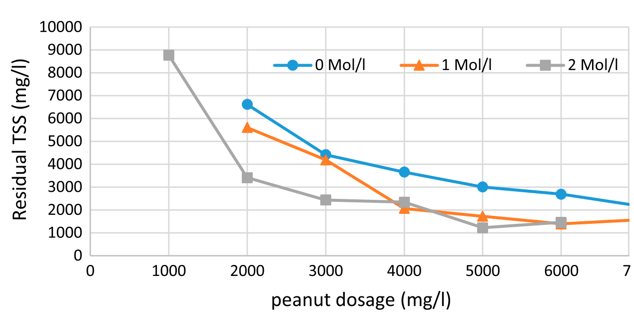

Fig. 2. Residual TSS vs. peanut dosage under different NaCl concentrations.

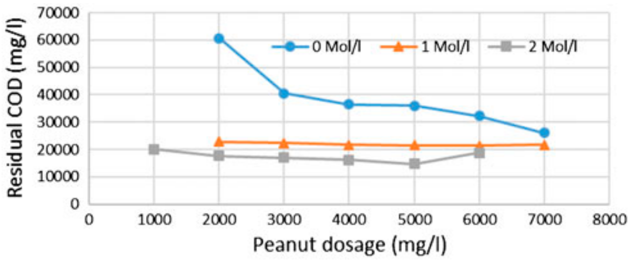

Fig. 3. Residual COD vs. peanut dosage under different NaCl concentrations.

Based on the preliminary results obtained in the present study, it can be summarized that peanut seeds after oil extraction (peanut cake) can function as an environment-friendly coagulant for pretreatment of POME. However, further treatment is needed to comply with effluent discharge standards. This could be in the form of filtration process or filtration plus aerobic treatment. It is recommended that more studies should be conducted on the effect of residual peanut on the other parameters such as, pH, alkalinity, BOD and conductivity.

4. Conclusions

Peanut seeds after oil extraction (peanut cake) have the potential to be used as a green coagulant for POME pretreatment. Extraction of coagulation active component from peanut seeds using NaCl reduced the optimum dosage and increased the removal efficiency of the constituents—the higher the NaCl concentration the lower the optimum dosage and the higher percentage of removal. In this regard, the optimum dosage obtained for 0, 1 and 2 mol/l NaCl was found to be 7,000, 6,000 and 5,000 mg/l, respectively. Further treatment of POME such as the filtration process is needed to obtain results that comply with the effluent discharge standards. Conducting studies on the effect of residual peanut on the other water quality parameters such as pH, alkalinity, BOD and conductivity are recommended.

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